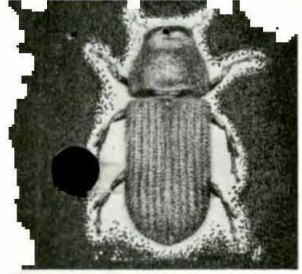

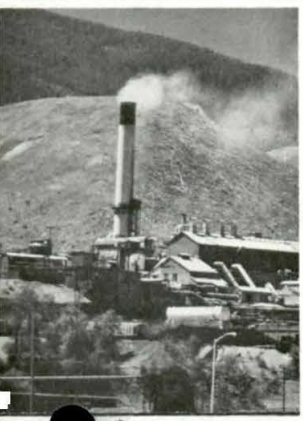

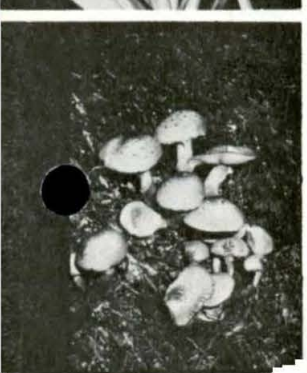

FOREST INSECT & DISEASE MANAGEMENT

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DROUGHT EFFECTS ON FOREST INSECTS AND DISEASES

by

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SUMMARY

BARK BEETLES

Drought has long been considered a contributing factor to epidemics of the mountain pine beetle. In lodgepole and ponderosa pine forests, beetle populations are not dependent upon drought conditions, but clear sunny days favor beetle development. Predictions for 1977 are for an increase in tree mortality and acreage infested, with new outbreaks developing in many susceptible stands.

Some evidence suggests that drought may trigger Douglas-fir beetle outbreaks, but drought more commonly functions to prolong infestations for 2-3 years.

Populations of pine engraver beetle are endemic within the Northern Region. Warm dry weather encourages infestation of standing trees, while cool moist weather renders trees largely immune to attack. Drought in late spring and early summer increases susceptibility of entire stands to Ips attack from mid-July to early fall.

White and grand fir mortality caused by fir engraver beetle is correlated with subnormal precipitation the previous year. If drought conditions prevail this year, an increase in fir mortality can be expected in 1978. Increased insect activity is expected particularly in trees infected with root rot fungi.

Flathead borers are normally endemic within the Northern Region; but may build up, attack and kill pole and mature size Douglas-fir, for two years following a year of subnormal precipitation.

Damage from secondary bark beetles is usually associated with primary bark beetles; however, in years of subnormal precipitation, secondary beetles can become primary in tree mortality.

DEFOLIATORS

Drought will significantly increase survival of western spruce budworm populations in the Northern Region if the drought continues after larvae emerge from hibernation. Hot, dry summers are conducive to budworm feeding, thus defoliation, top kill, and tree mortality may increase in some stands. These trees are already stressed by defoliators; with additional stress imposed by a reduction in soil moisture, many trees may become more susceptible to attack by bark beetles and other wood-boring insects.

DISEASES

Nonparasitic

Drought stress of trees affected by nonparasitic agents such as air pollutants, herbicides, etc., will likely compound damage. Both nonparasitic agents and drought affect host physiology, and effects appear additive. Such damage may be erroneously attributed to the drought situation when actually the primary cause is a nonparasitic agent.

Parasitic

Because most parasites acting above ground require moist periods to sporulate and infect plants, infection should be reduced. Drought stress will hasten the onset of observable foliar symptoms; however, damage will probably be reduced in the long run.

Drought may increase infection of host trees by root decay fungi, but damage will not be evident for several years. Trees already infected will likely succumb more rapidly than normal because of drought stress.

DIRECT EFFECTS

Insufficient water to maintain trees in a vigorous condition is the cause of summer drought damage. It may occur Region-wide, and is particularly noticeable in areas normally supporting trees with high moisture requirements. All species may be affected to some degree, but young shallow-rooted trees, of the least drought-hardy species, will be affected first. Tree location is an important factor in development of

symptoms; and effects may range from none to tree mortality. Symptoms range from foliage wilting or discoloration, reduced growth, twig dieback, or tree mortality, and may occur singly or in combination. Abnormally early yellowing and needle shedding occur following prolonged drought of mild severity. In true firs, this causes entire age classes of oldest age needles to discolor, and probably represents a survival mechanism. Chronic drought injury is slow in developing and difficult to diagnose. When drought severity increases, the more succulent tissues are affected first. Damage progresses from the top downward and inward. Severity of damage is usually related to severity of drought (Williams In Prep.).

Defoliation of the midcrown of Douglas-fir trees on Vancouver Island followed the hot dry summer of 1967. Since rainfall was 80 percent below average, trees growing on shallow soils with small moisture storage capacities were undoubtedly subject to abnormal stress. The prevalence of affected trees was evidence that symptoms observed were drought related. In the spring of 1968, the year following the drought, reddening of foliage in a similar midcrown position occurred on other trees. The position of these effects could not be attributed to localized fungus infections, insects, or microclimatic influences (McMinn & Funk 1970).

INDIRECT EFFECTS

BARK BEETLES

MOUNTAIN PINE BEETLE

Emphasis has almost always been on the effect of drought on the tree, but little on the beetle (Blackman 1931 is an exception). The beetle fares well when cloud cover is minimal. Warm weather promotes rapid development and early emergence. Consequently, new brood is able to develop to large size prior to the onset of winter, and is better able to survive in the later instars (Amman 1973).

The mountain pine beetle, Dendroctonus ponderosae Hopk., is the most serious insect pest of lodgepole, ponderosa, and western white pine in the Northern Region. Currently, infestations are epidemic on about 900,000 acres, with the beetle accounting for over 500 million board foot loss in lodgepole, ponderosa, and western white pine stands, or 77 percent of the total timber killed in 1976 in the Northern Region. Forests incurring the most severe infestations in lodgepole pine stands are the Beaverhead, Gallatin, Lolo, Kootenai, and Flathead, with a massive increase of infested acreage developing on the west side of Glacier National Park in Montana, and Clearwater National Forest, Idaho. Infestations persisted in second growth ponderosa pine stands on Federal, State, and private lands on and adjacent to the Helena, Lolo, Lewis and Clark, and Bitterroot National Forests in Montana. In Idaho, infestations

in western white pine stands occur on the Clearwater, St. Joe, and Idaho Panhandle National Forests. Small but significant tree mortality is occurring in ponderosa pine stands of the Idaho Panhandle National Forests and Nezperce National Forest in Idaho.

Predictions for 1977 are for an increase in tree mortality and acreage infested in all areas, and new outbreaks could develop in many susceptible stands.

There are two theories concerning the occurrence of mountain pine beetle epidemics in lodgepole pine: (1) trees are weakened by some stress factor such as drought or pathogens which predisposes them to infestation by the mountain pine beetle, or (2) trees must grow into optimal physiological conditions for brood survival consisting of adequate food (phloem) and moisture which requires good blue stain fungal development for regulation during beetle development. These conditions usually are met when trees are changing from juvenile to mature (about 60 years of age). Vigorous trees often drown attacking beetles with excessive resin flow, but tree vigor and resin flow may be reduced by prolonged drought (Prebble 1951).

Lodgepole Pine

Most outbreaks of the mountain pine beetle in lodgepole pine in Canada have occurred during or immediately following drought periods (Prebble 1951). All large outbreaks of the mountain pine beetle in the British Columbia Interior, between 1920 and 1935, occurred during a long period of subnormal precipitation and depressed tree growth. Hopping and Mathers (1945) reported that two outbreaks (Kootenay and Banif) in lodgepole pine occurred during a period of deficient moisture.

Growth data from lodgepole pine in the Bear River drainage on the north slope of the Uinta Mountains in Utah showed that the present infestation which increased sharply about 1970, occurred during moist years and continued to spread under average to better than average precipitation. Trees infested in 1968 were few in number and widely distributed in the stands. These trees showed increased growth starting about 1959. In addition, data showed that the beetle preferred trees that were growing faster than their nearest neighbors.

Even though a small amount of rain falls during the summer in most lodgepole pine forests, trees may not be in drought-stressed condition because growth is primarily related to the amount of snow that falls during the winter. This seems to be adequate to carry the tree through the growth period (to the latter part of July). Amman[1/] concludes that the mountain pine beetle in lodgepole pine forests are not dependent upon drought conditions, but clear sunny days favor beetle development rather than tree stress.

1/ G. D. Amman, Personal communication, April 1977.

Ponderosa Pine

Beal (1943) studied weather records in relation to 13 infestations of the Black Hills beetle (mountain pine beetle) that occurred between 1895 and 1939. He found that the eight most recent infestations plus the old Black Hills epidemic occurred during years of subnormal precipitation when tree growth was below normal. Two infestations began in wet years, but increased in aggressiveness during years of slightly reduced rainfall when tree growth was also subnormal. The remaining two outbreaks originated and continued through years of slightly subnormal precipitation and tree growth. Beal concluded that many outbreaks are positively related to deficient precipitation, but that some epidemics are governed by other causes. The mechanism involved seems to be the inability of the host tree to produce copious amounts of resin thereby pitching out beetles as is the case during normal moisture conditions.

Mature

Blackman (1931) studied the Black Hills beetle (mountain pine beetle) infestations in ponderosa pine on the Kaibab Plateau. He stated that D. ponderosae populations are not dependent upon drought for building to epidemic levels. Blackman found that epidemics started during periods of several years of rapid tree growth and reached their apex when the growth curve peaked, or, in one case, had started to decline. He found that the end of epidemics came, with one exception, with a great decline in the growth curve of the trees. He suggested that an increase in moisture available to the tree results in increased brood survival during average or better than average precipitation. A marked deficiency in available moisture extended over a period of several years results in decreased brood survival, thus bringing the epidemic under natural control by drought.

Second-Growth

Mountain pine beetle is epidemic on 1,300 acres with an estimated volume loss of 62,700 bd. ft. on the Nezperce National Forest in Idaho, and 1,229 acres with an estimated 140,400 bd. ft. volume loss on the Bitterroot, Lolo, Helena, and Lewis and Clark National Forests and adjoining State and private lands in Montana. Predictions are for increased tree mortality in all areas in 1977.

Infestations in second-growth ponderosa pine develop in stands which have been essentially undisturbed for many years and occur in periods of both normal and deficient precipitation. However, stands in the Black Hills of South Dakota and in Oregon show that outbreaks in second-growth ponderosa pine stands occur in trees between the ages of 50 to 100 years, and that it occurs earlier in stands on good sites than in ones on poor sites. Stands which average less than 6 inches d.b.h. do not sustain severe

losses. Most outbreaks occur in stands which average at least 8 to 12 inches d.b.h. It appears that phloem thickness of small trees is insufficient to allow a beetle population buildup. High stand density is characteristic of second-growth ponderosa pine stands. Good quality growing sites can support more dense stands than poor sites without suffering severe beetle damage. Drought could be a factor influencing development of outbreaks in second-growth ponderosa pine stands. Intensive competition between trees, a high stand density, and the effect on tree resistance to beetle attack are major contributing factors in outbreak tree killing.

DOUGLAS-FIR BARK BEETLE

Douglas-fir beetle, Dendroctonus pseudotsugae Hopk., infestations occur on the Bitterroot, Custer, Flathead, Lolo, Lewis and Clark, and Kootenai National Forests in Montana; and on the Clearwater, Idaho Panhandle, and Nezperce National Forests in Idaho. About 4,000 acres are infested in all areas with an estimated 203,095 bd. ft. volume loss in 1976. Increased tree mortality could occur in 1977.

There is evidence that drought triggers some outbreaks, but more commonly drought prolongs infestations for 2 to 3 years after they have developed to epidemic level.[2/]

PINE ENGRAVER BEETLES - Ips spp.

Ips populations are endemic in the Region. Most outbreaks can be traced to environmental factors such as stand disturbances, climate, and site. Probably the most important environmental factor influencing an Ips outbreak is weather.

Attacks on living trees are closely associated with availability of soil moisture and temperature. Warm dry weather encourages infestations in standing trees, whereas cool moist weather renders living trees largely immune to attack. When drought occurs in late spring and early summer, entire stands can be adversely affected and become susceptible to Ips attack from mid-July to early fall. The degree of susceptibility varies with several conditions. In drought areas, phloem moisture in individual trees decreases as the season progresses; this is dependent on moisture and temperature during winter and spring (Dolph 1965).

Two key factors influence the risk of Ips epidemics: (1) the supply of fresh green slash in the spring and early summer months, and (2) precipitation through March. When cool damp conditions persist into May and June, the risk of Ips outbreaks in standing trees is small. In hot dry years, occasional Ips outbreaks develop in green trees without an association with slash.

2/ Furniss, M. M. Personal Communication 1976.

Hall (1956) showed that the percent of normal precipitation between April and July was sufficient to predict the degree of Ips outbreaks in California. Predictions are determined as follows:

Precipitation percent of normal	Prediction degree of loss
150 or greater	Very light
100 to 150	Light
75 to 100	Medium
Less than 75	Heavy

This method has been used in California since 1950 and predictions have been 75 percent correct. This same method was applied by Dolph (1965) in Oregon. For the 7-year period 1957 through 1963, precipitation fluctuated from a high of 7.8 inches (137 percent of average) in 1958 to a low of 3.6 inches (63 percent of average) in 1961. Analysis of the data showed that Hall's method was applicable in Oregon. If moisture is 75 percent of average or less, moderate to heavy tree mortality of second-growth, less than 80-year-old, overstocked ponderosa pine stands can be expected. Damage may continue 2 to 3 years, especially in trees larger than pole size. Under condition of extreme drought stress, large groups of young sawtimber trees, up to 30 inches d.b.h., have been infested.

FIR ENGRAVER BEETLE - Scolytus ventralis LeC.

Fir engraver beetle populations are epidemic in grand fir stands on 9,000 acres of the Clearwater, Nezperce, and Idaho Panhandle National Forests in Idaho, with an estimated 3,745,960 bd. ft. volume loss in 1976. Localized infestations occur on the Flathead and Lolo National Forests and adjacent State and private lands in Montana. Aerial surveys in 1976 showed infestations on 6,400 acres containing about 97,000 bd. ft. (Bousfield & Carlson 1977). Predictions are for increased activity in 1977.

Subnormal precipitation coinciding with subnormal tree growth of white and grand fir caused an increase in beetle-caused tree mortality the following year (Ashraf & Berryman 1969). Annual precipitation is more significant in white fir than seasonal precipitation. Drought adversely affects growth of fir in the dominant and intermediate crown classes.

In California fir stands (Ashraf & Berryman 1969; Farrell 1973; Farrell & Hall 1975), the period of greatest beetle attack coincided generally with subnormal precipitation; and attacks are preceded by at least 1 year of subnormal or declining growth. An increased amount of logging slash present during years of subnormal precipitation results in an increase in beetle attack and provides a source of breeding material for population buildup.

FLATHEADED BORER - Melanophila drummondi Kby.

Infestations are endemic in Region 1 at present. Populations of this beetle do build up, attack, and kill pole size and mature Douglas-fir following years of subnormal precipitation. Moisture-stressed Douglas-fir growing on ridges, rocky outcrops, poor sites, or infected with root rot, are susceptible to attack.

In 1968, several hundred pole size Douglas-fir were killed along the east shore of Flathead Lake following the 1967 drought. And in 1974, several hundred Douglas-fir were killed along Dworshak Reservoir following the 1973 drought.

SECONDARY BARK BEETLES - Ips spp., Pityogenes spp., Pityophthorous spp.

Gibson (1938) found that damage from secondary bark beetles is usually associated with primary ones (Dendroctonus spp.). Most activity occurs in tops and limbs of trees killed by primary beetles.

These beetles also infest trees that had been weakened by fire, lightning, or severely injured by porcupines then were infested by mountain pine beetle. These trees usually show subnormal growth, have thin phloem, and produce few beetles. However, these trees are attractive to secondary bark beetles which can fly and attack prior to, or in association with, the mountain pine beetle resulting in intraspecific competition (crowding) for brood space. This more commonly occurs during mountain pine beetle population declines, or during endemic situations.

In drought years when tree vigor and resistance are depressed, secondary beetles can attack and kill trees not previously infested by primary beetles. They do not build to epidemic levels, tree mortality is readily visible for only 1 year, and evidence of infestation subsides rapidly.

DEFOLIATORS

WESTERN SPRUCE BUDWORM

Montana

Defoliation caused by the western spruce budworm, Choristoneura occidentalis Free., has been evident in Montana the past 5 years with nearly 2.5 million acres currently infested. Epidemic infestation occurs on the Beaverhead, Bitterroot, Deerlodge, Helena, Gallatin, Lewis and Clark, and Lolo National Forests and surrounding State and private lands (Tunnock 1977).

An impact survey conducted on the Gallatin National Forest in August and September 1976 showed considerable damage in terms of top kill and tree mortality. Damage on the Gardiner District showed 52.8 percent of the volume on one stand of Douglas-fir was top killed and 16.7 percent of the volume was dead because of repeated defoliation. No mortality in trees greater than 5 inches d.b.h. was noted on four stands examined on the Livingston District. However, top kill ranged from 34.3 to 61.1 percent of the volume. A total of six stands were examined on the Bozeman District, and mortality ranged from 0 to 12.2 percent of the volume. In one stand 79 percent of the Douglas-fir was top killed. Four stands were examined on the Gallatin Ranger District and top kill volume ranged from 7 to 54.8 percent. Budworm-caused mortality occurred in three of the four stands examined and accounted for 5.2 percent of the volume loss.

In addition, trees under 5 inches d.b.h. (which are not included in volume estimates) were evaluated to determine extent of damage in this size class. Mortality was sporadic in most areas examined; however, one stand showed 84 percent of the trees less than 5 inches d.b.h. were dead on the Gallatin Ranger District. Top kill of trees less than 5 inches d.b.h. occurred in most areas; however, top kill was absent in some stands on the Bozeman Ranger District. Top kill on the Gallatin Ranger District ranged from 15 to 75.7 percent; and on the Gardiner Ranger District the two stands examined had 74.9 and 77.2 percent top kill respectively.3/

Egg mass surveys completed last fall indicate that the infestations will continue at nearly the same level in 1977 with some increase in defoliation on portions of the Beaverhead, Bitterroot, Deerlodge, Helena, Gallatin, Lewis and Clark, and Lolo National Forests (Tunnock 1977).

Idaho

The three Idaho National Forsts in the Region presently contain 655,000 acres of budworm infestation.

Damage surveys to determine effects of budworm defoliation have been conducted in northern Idaho for 4 years. Defoliation by budworm has caused considerable top kill and measurable growth loss.

Twenty-two percent of the trees were top killed after seven years of light to moderate defoliation, and fifty-four percent were top killed in more severely defoliated trees on the Nezperce National Forest (Bousfield & Williams 1977).

In mixed forests, grand fir and subalpine fir are most damaged by budworm. The following shows growth by tree species as a percent of normal:

3/ Bousfield, W. E. Personal communication to Gallatin NF, 1977.

Grand fir	-22.28
Subalpine fir	-18.88
Spruce	- 4.10
Larch	+ 4.09
Douglas-fir	- 8.98
Lodgepole pine	- 1.02
Ponderosa pine	+ 3.37

Trees exhibit growth reduction after 4 or more years of budworm defoliation. Areas on the Nezperce National Forest showed reduction related to severity of damage (Bousfield 1976):

Percent growth loss	
Lightly damaged stands	Moderate to severely damaged stands
-2.66	-17.64

Egg mass surveys in fall 1976 indicate moderate defoliation on portions of the Idaho Panhandle National Forests and light defoliation on the Nezperce and Clearwater National Forests in 1977 (Tunnock 1977).

Drought conditions to the first of May will be insignificant on western spruce budworm populations. Short dry summers are conducive to budworm feeding and could result in severe defoliation. This in turn may result in top killing and tree mortality in some stands.[4/]

DROUGHT-BARK BEETLE-DEFOLIATOR RELATIONSHIP

If drought conditions persist into the summer, we can expect an increase in bark beetle (Douglas-fir beetle, western pine beetle, mountain pine beetle, fir engraver beetle, secondary beetles, flatheaded wood borers) activity in some grand fir/Douglas-fir stands defoliated by western spruce budworm and Douglas-fir tussock moth in northern Idaho, and western spruce budworm in Montana; and in ponderosa pine stands defoliated during 1973-74 by the pine butterfly (Neophasia menapia Feld.) in the Bitterroot National Forest in Montana.

These trees are already stressed by defoliators. With additional stress imposed by a reduction in soil moisture from drought, many trees may become more susceptible to attack by bark beetles and wood-boring insects.

The probability of bark beetle infestation following defoliation by other insects is an important consideration in strategy designed to manage forest insects. Although defoliation alone may cause growth reduction, dieback, and mortality, damage caused by subsequent bark beetle infestation may be even more severe. Little is known about the relationship between defoliation and subsequent bark beetle attack, but

4/ Fellin, D. G. Personal communication 1977.

bark beetles have been associated with tree mortality following defoliation by several insects (McMullen In Press).

Wickman (1958) records that of the 20.8 percent mortality in white fir over 11 inches d.b.h. following defoliation by Douglas-fir tussock moth, 19.8 percent was associated with damage by other insects, the fir engraver beetle and the round-headed fir borer. Berryman (1973) associated fir engraver populations with epidemics of the Douglas-fir tussock moth in grand fir. Dewey et al. (1974) related degree of defoliation by a pine looper (Phaeoura mexicanaria) on ponderosa pine with pine engraver beetle attack. Of the most severely defoliated trees, 75 percent were killed by bark beetles, whereas only 3 percent of partially defoliated trees were killed by beetles. Beetle activity declined 1 year following defoliation. Evenden (1940) found mortality only in the most severely defoliated trees following defoliation by pine butterfly on ponderosa pine. Fifty-four percent of the mortality was associated with western pine beetle. Mortality due to defoliation alone continued for 8 years after peak defoliation, whereas 13 of the 14 trees with western pine beetle had died by the fifth year following defoliation. This difference in duration of mortality suggests that the beetle was simply taking advantage of weakened trees and causing little extra mortality. Wickman (in McMullen, In Press) records that mortality following Douglas-fir tussock moth defoliation on grand fir and Douglas-fir due to bark beetle attack was related to degree of defoliation. On grand fir, mortality due to bark beetle was distributed fairly evenly through the 75 to 100 percent defoliation categories, with the highest level (7 percent) at the 90 percent category. On Douglas-fir, mortality was distributed between the 25 to 90 percent defoliation categories with the 90 percent category again suffering the highest mortality (7 percent). The initial damage occurred primarily in the high defoliation categories and most damage occurred the second year after defoliation started. In addition, he details difference in intensity of beetle-related mortality in tussock moth-defoliated fir stands, and concludes that trees with over 90 percent defoliation have a high probability of dying whether attacked by bark beetles or not. The important aspect with bark beetles is whether or not there is the potential of a population buildup which would be capable of killing lightly defoliated or undefoliated trees.

DISEASES

Nonparasitic

Drought stress on trees affected by nonparasitic agents such as herbicides, air pollutants, and excess salt or water will likely compound damage. All these agents affect host physiology, and the effects are somewhat additive. Damage may be attributed to drought, but the other agents are the primary cause.

An example is autumn needle shed, a natural process hastened by drought. The oldest needles of many conifers turn yellow, then red-brown, and are shed during autumn. Individual needles discolor uniformly and usually lack insect damage or fungal fruiting bodies. This is a natural process most noticeable in pines where entire age classes of oldest needles (3-6 years old) are shed in the fall. Doulgas-fir and true firs shed much older needles, but an entire age class of needles is usually not shed all at once (Williams In Prep.).

Parasitic

Pathogenic agents which affect above-ground plant parts require moist periods to sporulate and infect the host. If moist conditions do not occur, infection and damage should be reduced. Damage is not generally seen for 1 or more years following infection. Drought stress may hasten onset of visible foliar symptoms and give an appearance of increased severity, but actual damage will be less because of drought.

Root pathogens are not directly dependent upon atmospheric moisture for infection and colonization. Many root pathogens are opportunists, and when stress is imposed, a host's defense mechanisms are less effective and the pathogen is able to more easily infect or to more rapidly colonize the host. Drought may increase infection of conifers by root pathogens, and trees already infected by root pathogens may succumb more rapidly than normal. Several nursery pathogens of conifer seedlings are more active at elevated temperatures. If high temperatures occur shortly after seed germination, loss from root rot will be higher than normal, but resulting damage may not be evident for several years.

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